Attachment 1

Paso Robles Groundwater Basin Model Update

Executive Summary

PREPARED FOR:

San Luis Obispo County Flood Control and Water Conservation District

December 23, 2014

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SAN LUIS OBISPO COUNTY FLOOD CONTROL AND WATER CONSERVATION DISTRICT
PASO ROBLES GROUNDWATER BASIN MODEL UPDATE

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1.0 EXECUTIVE SUMMARY

1.1 Introduction

Local agencies, including the San Luis Obispo County Flood Control and Water Conservation District (District) and local stakeholders are working cooperatively to manage the Paso Robles Groundwater Basin (Basin). Work has included extensive monitoring, development of a management plan, conduct of studies, and development in 2005 of a numerical groundwater flow model (Basin Model). This report summarizes the Basin Model Update, which was undertaken to extend the model study period over water years[1] 1981-2011, to improve the water balance assessment and refine the perennial yield, and to evaluate the Basin's response to "Growth" and "No Growth" scenarios projected over the period water years 2012-2040.

The study area consists of the Paso Robles Groundwater Basin which encompasses 790 square miles in the upper Salinas River watershed in northern San Luis Obispo County and southern Monterey County. The initial Basin Model was constructed using MODFLOW, the widely-accepted groundwater flow modeling code[2] developed by the United States Geologic Survey. Development of the initial Basin Model involved definition of the geologic framework including basin boundaries (such as the boundary between the Atascadero Sub-Basin and the remainder of the Basin) and four layers representing the recent alluvial deposits and portions of the Paso Robles Formation. The initial Basin Model also included estimation of aquifer properties and evaluation of the water balance for the period water years 1981-1997. This Basin Model Update did not change the geologic framework, but focused on update and refinement of the water balance.

[1] A water year is defined as the period from October 1 through September 30.

[2] Groundwater models are mathematical representations of the movement (both lateral and vertical) of groundwater within a defined system (i.e., basin). These models include assumptions and simplifications made for various specific purposes.

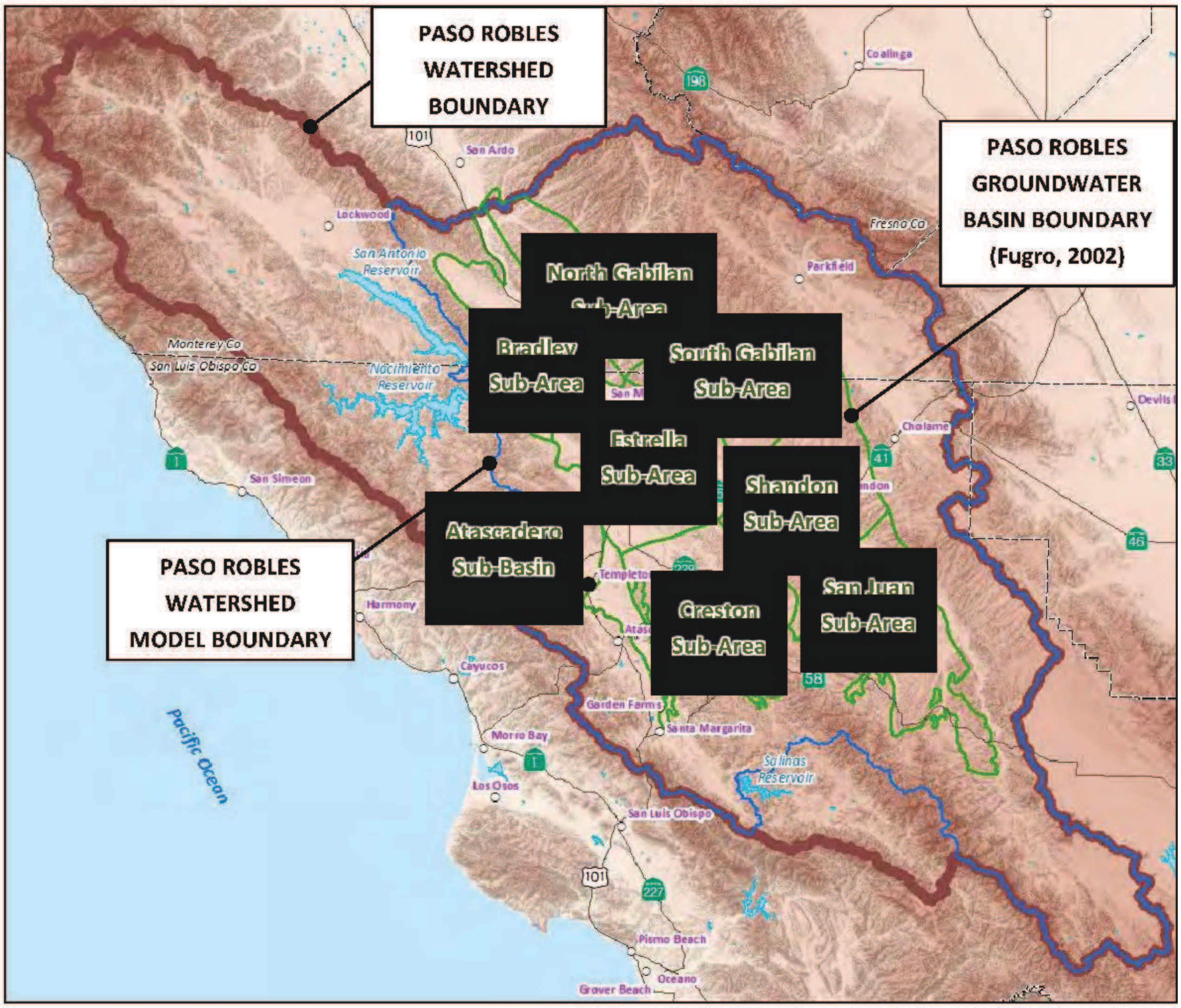


Figure ES-1. Overview of the Paso Robles Groundwater Basin and Surrounding Watershed

1.2 Water Balance Estimation

The Basin Model Update evaluated each component of the water balance independently using available data. The primary groundwater recharge components for the Basin are:

- Deep percolation of direct precipitation,
- Deep percolation of streambed seepage,
- Deep percolation of applied irrigation water,
- Subsurface inflows through the Basin boundary,
- Deep percolation of discharged treated wastewater effluent, and
- Recharge from urban water and sewer pipe leakage.

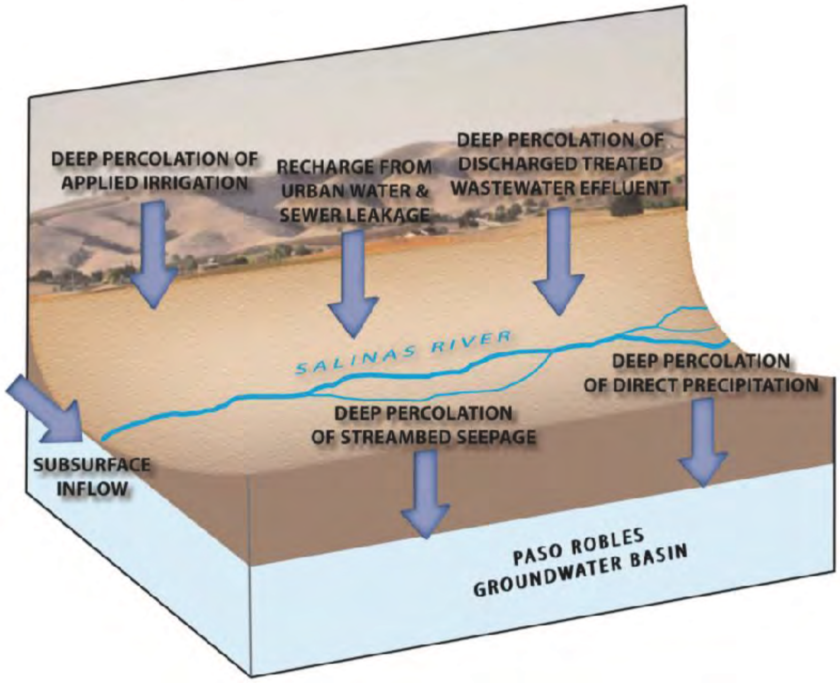


Figure ES-2. Primary Recharge Components for the Paso Robles Groundwater Basin

This report provides detailed description of the data and methodologies used in evaluating each recharge component.

A major new feature was development of a rainfall-runoff model[3] of the watershed[4] that is tributary to the Basin (see Figure ES-1). Such watershed hydrologic modeling uses extensive data to characterize the water balance and hydrologic processes that occur in a watershed. These data include land surface elevations, soil types, land use, precipitation, evaporation, streamflow, surface diversions, reservoir releases, wastewater recharge, crop coefficients, and irrigation efficiency. Historical data were collected, compiled (mostly in spreadsheets and a GIS database), and reviewed prior to incorporating them into the Basin Watershed Model. The available data are summarized in this report and have been made available to the District.

In addition, this report describes the primary steps used to construct the Basin Watershed Model

[3] The Watershed Model was developed using the Hydrologic Simulation Program – FORTRAN (HSPF), a successor to the FORTRAN version of the Stanford Watershed Model, widely-used codes developed with support of the United States Environmental Protection Agency (EPA).

[4] Surface water occurring in the watershed areas above the Nacimiento, San Antonio, and Salinas Reservoirs represent an external source of water coming into the Basin Watershed Model area. As such, daily releases from each reservoir are included as input to the Basin Watershed Model to help establish a water balance.

involving 81 defined sub-watersheds and calibrating to four streamflow gaging stations with relatively long records. These gaging stations include the Salinas River near Bradley (at the outlet of the Basin), Salinas River above Paso Robles, Estrella River near Estrella, and Santa Margarita Creek near Santa Margarita; comparison of model-simulated and measured streamflow indicates a very good match for the Salinas River near Bradley gaging station and good or fair matches for the other stations.

The Basin Watershed Model provided independent analysis of recharge to the Basin, including subsurface inflow and streambed percolation; issues in the estimation of these recharge components had been identified by the initial Paso Robles Basin modelers and later reviewers. These components remain difficult to assess accurately, reflecting a lack of data on percolation rates, streamflow and nearby groundwater levels, particularly around the margins of the Basin. As a result, these components became a major topic of the peer review conducted near the end of the Basin Model Update process and a focus of subsequent recommendations for additional model refinement.

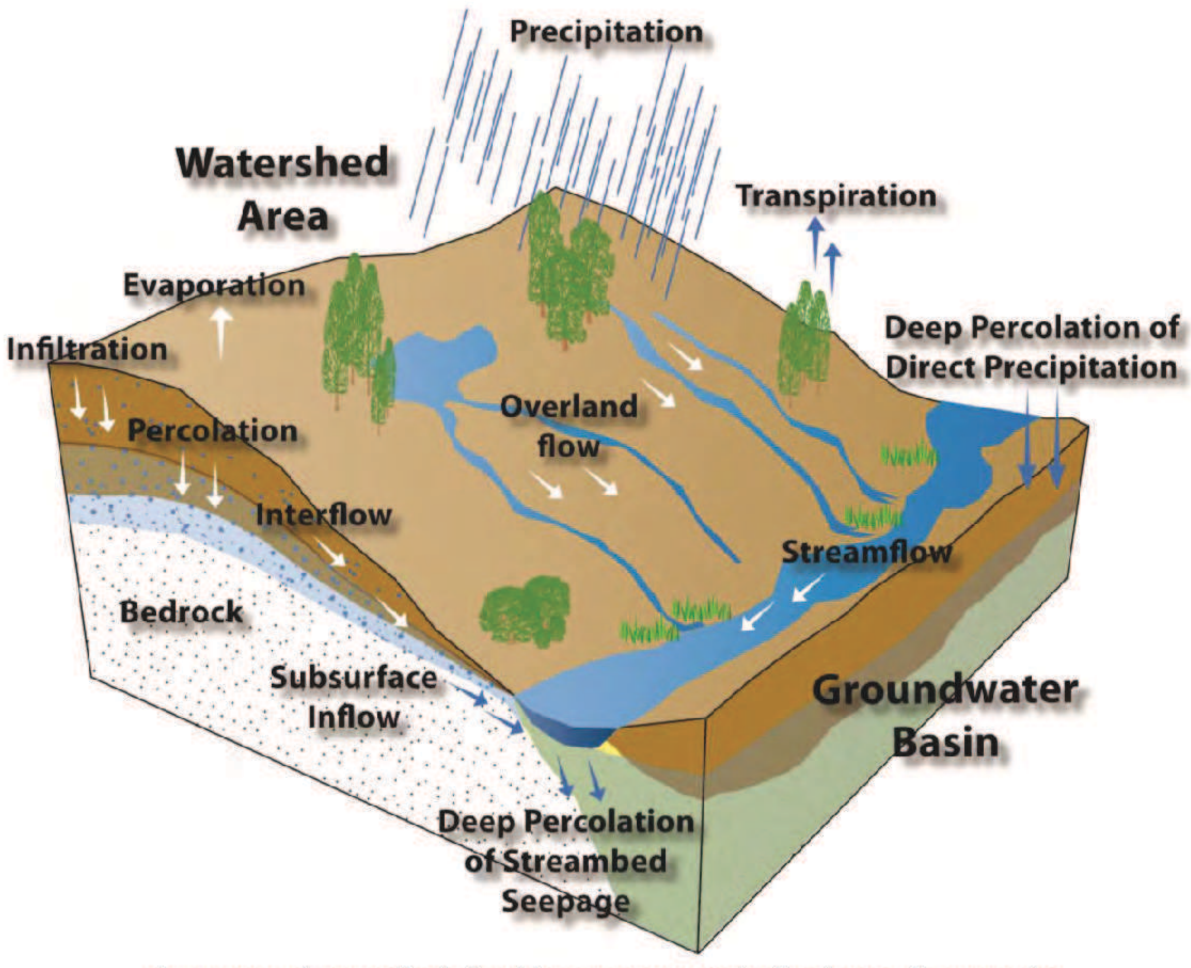


Figure ES-3. Diagram of Relationship Between Watershed and Groundwater Basin

The primary groundwater discharge components for the Basin are:

- Agricultural pumping (average 68% for 1981-2011),
- Municipal pumping (11% for 1981-2011),
- Private Domestic pumping (3% for 1981-2011),
- Small commercial pumping (2% for 1981-2011),
- Evapotranspiration (ET) by riparian vegetation (3% for 1981-2011),
- Groundwater discharge to rivers (12% for 1981-2011) and
- Subsurface outflow (1% for 1981-2011).

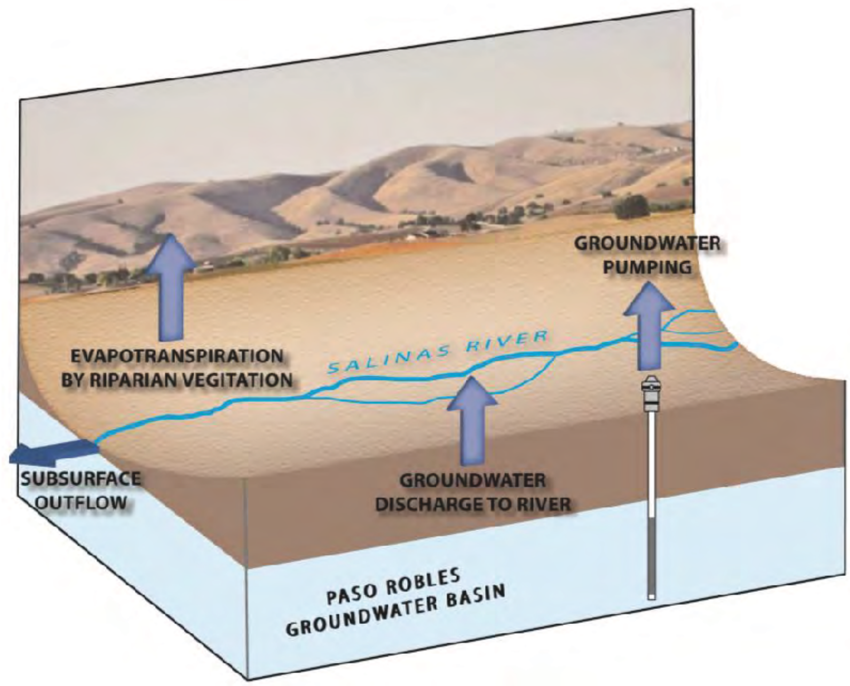


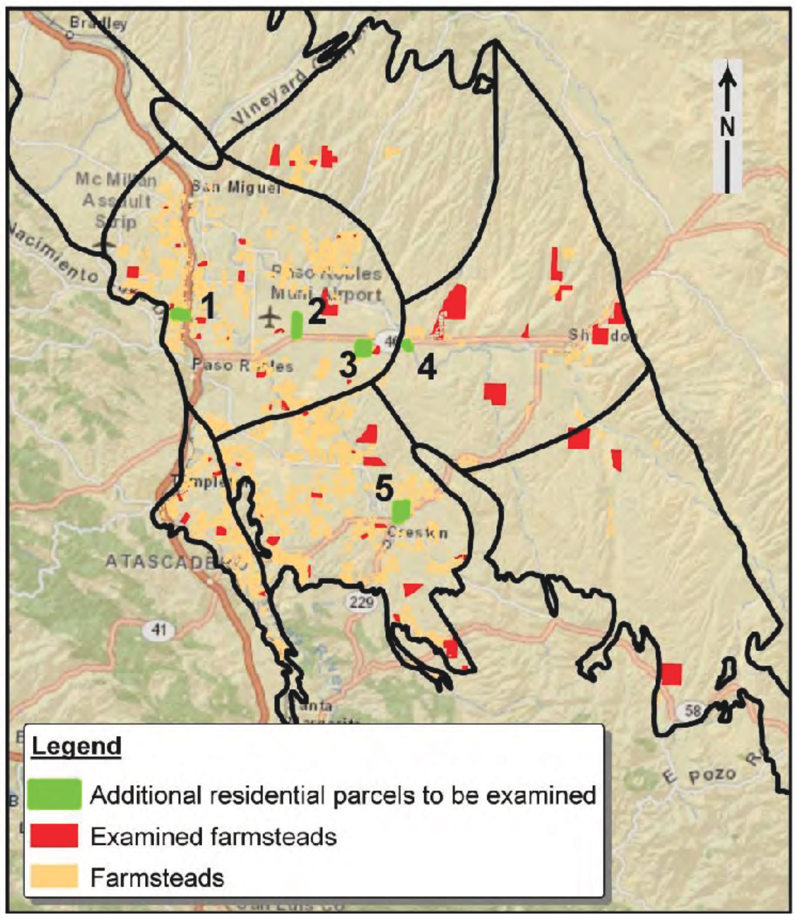
Figure ES-4. Primary Discharge Components for the Paso Robles Groundwater Basin

Of the discharge components, agricultural pumping accounts for the major portion (averaging about 68% over the model study period). Agricultural pumping is not metered and thus was subject to detailed analysis. As described in this report, this included development of crop-specific daily soil moisture water balances accounting for soil available water capacity, daily rainfall and reference evapotranspiration, crop water coefficient, bare soil evaporation, and increasing irrigation efficiency over time. Annual crop acreages estimated from Department of Water Resources (DWR) land use maps, digital San Luis Obispo County crop coverage maps for 2000 through 2011, and digital coverage of Monterey County 2012 crops. Crop acreages within groundwater basin boundaries from 2000 to 2010 were corrected/verified based on review of historical aerial photography.

Given the rapid increase in vineyards to dominate irrigated acreage (vineyards are more than 80% of irrigated acreage in the Basin), considerable attention was given to factors in vineyard water demand such as frost protection, reduced deficit irrigation (RDI) management, and increasing use of RDI management over time.

A relatively small but increasing discharge component is rural domestic pumping. This was a subject of concern because it is largely unmetered. Because meter data are lacking, previous studies (including the Phase I Study) relied on application of an assumed water demand factor of 1.7 AFY per dwelling unit (DU). The 2012 MWP also assumed a single water demand factor, in this case, 1.0 AFY/DU. This was significantly smaller and highlighted the uncertainty. Moreover, rural residences are quite variable—ranging from modest farmsteads to landscaped estates—suggesting that the variability of associated water demand was not evaluated adequately, particularly with regard to the extent of irrigated landscaping.

This concern was addressed in a special survey for this Basin Model Update and in a parallel survey for the concurrent Salt Nutrient Management Plan. The SNMP investigation focused on a San Luis Obispo County land use category termed *farmstead*, examined 59 farmsteads across the groundwater basin, and measured the landscaped areas, which averaged 0.13 acres per farmstead. For this Basin Model Update, a slightly different survey was performed focusing on five rural residential areas across the basin. The average landscape area was determined, resulting in a representative value is 0.13 acres per parcel, which happens to be the same value as that derived from the SNMP survey. Accordingly, both studies showed that rural residents irrigate a limited and fairly uniform acreage. For this study, available rural water demand information was used to estimate water demand per rural residential at 0.75 AFY/dwelling unit. This is a reasonable estimate of rural domestic use based on actual data. Of this amount, an average 38% is used indoors and can be assumed to return to the basin through onsite septic systems. An average of 62% is used outdoors and can be assumed consumed or lost to ET.



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1.3 Hydraulic Separation of Atascadero Sub-Basin

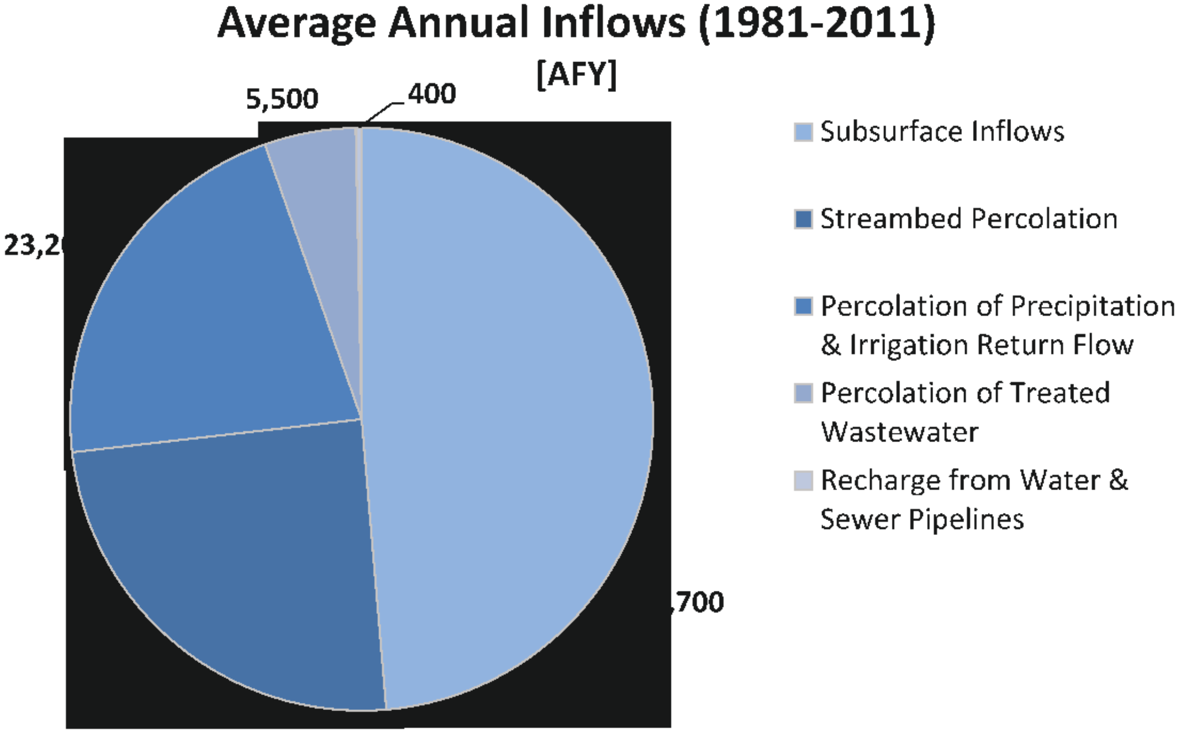
The geologic conceptual model developed during the Phase I Study (Fugro and Cleath, 2002) defined the boundaries and hydrogeologic layers within the Basin, and identified the Atascadero Sub-Basin as a sub-basin with partial hydraulic separation across the Rinconada Fault from the remainder of the Basin[5]. An attempt to reevaluate the degree of separation was made for this Basin Model Update through review of post-2007 background reports and documents, driller's logs and well construction information, historic groundwater elevations, and historic groundwater pumping for wells located in the area of the reevaluation. Results of the reevaluation revealed there is a lack of wells and respective data within close proximity to the Rinconada Fault to adequately determine the degree of separation. Accordingly, the barrier conductivity values that were established by the Phase I Study were maintained for this Basin Model Update.

1.4 Basin Model Update

The original Basin Model was calibrated for water years 1981 through 1997 with a semiannual stress period. This update extended the model period to water year 2011, and replaced the recharge and discharge terms using the updated water balance analysis. This report provides details on the modeling software (MODFLOW packages) used to handle the estimated Basin inflows and outflows. The model domain, cell size and aquifer layering were unchanged from the original model. The updated Basin Model was run successfully with semiannual stress periods and evaluated in terms of its ability to produce simulated groundwater level trends that match observed trends; this evaluation triggered a recalibration of the model to improve its accuracy. Recalibration involved adjustments (using professional judgment and staying within reasonable bounds) to aquifer properties, and inflow and outflow terms. The recalibrated Basin Model is able (within industry standards) to simulate observed changes in groundwater levels that are driven by hydrological and groundwater pumping fluctuations.

Based on results of the recalibration run, model-generated total annual inflow for 1981-2011 ranged from 24,700 AF to 384,300 AF with an annual average of 108,400 AFY. Total annual outflow calculated by the updated Basin Model ranged from 84,400 AF to 142,160 AF with an annual average of 110,800 AF over the period 1981-2011. Applying the equation for change in groundwater storage (inflow minus outflow), the average annual change in groundwater storage for 1981-2011 is approximately -2,400 AFY.

[5] Except for any separation of the Atascadero Sub-Basin, the Basin is considered to be an interconnected groundwater basin.



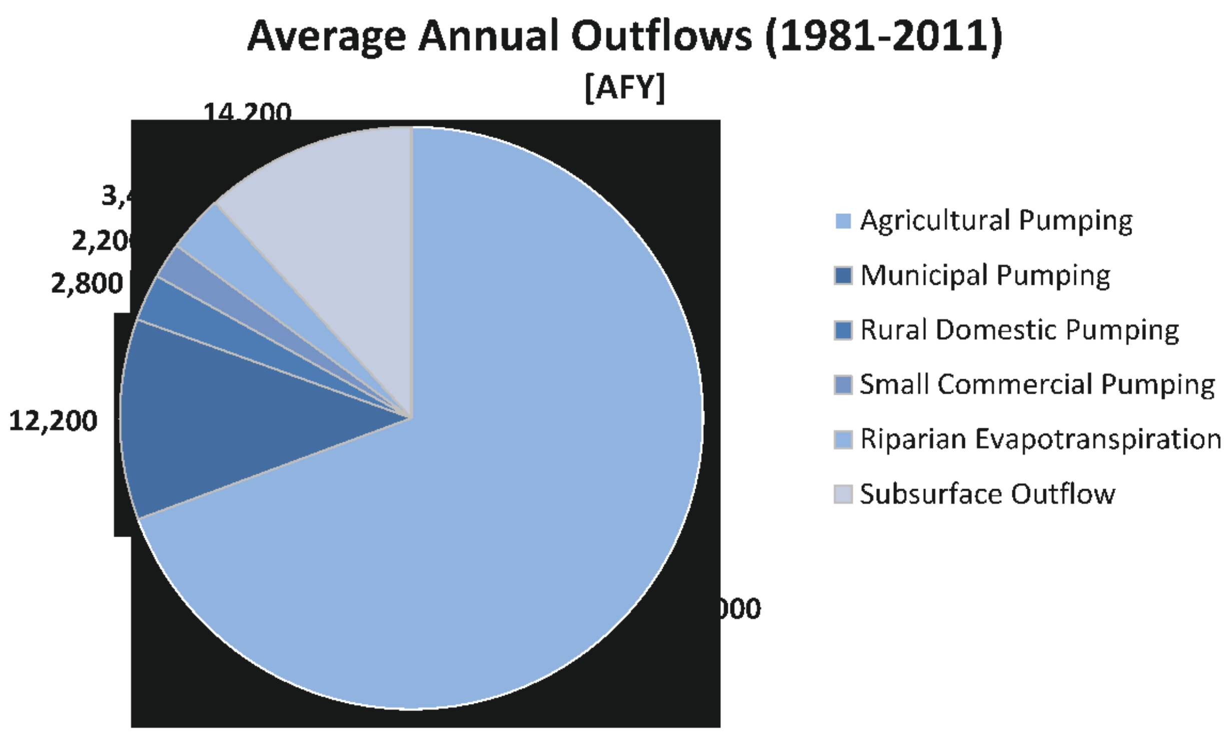


Figure ES-6. Average Annual Inflows and Outflows for the Paso Robles Groundwater Basin

Sensitivity analysis was performed on the recalibrated Basin Model in order to assess the model input parameters that have the greatest effects on the model's simulation results. The sensitivity analysis indicates that the Basin Model is most sensitive to changes to groundwater pumping and recharge from streambed percolation.

1.5 Perennial Yield Estimate

The maximum quantity of water that is available from a groundwater basin on a perennial basis is limited by the possible harmful side effects that can be caused by both pumping and operation of wells within the basin. The perennial yield, for purposes of this report is defined as:

Perennial Yield = Groundwater Pumping +/- Change in Storage

For the purposes of discussing perennial yield, the base period 1982 to 2010 covers wet, dry and average hydrologic cycles for the groundwater basin. The updated estimate for the perennial yield of the Basin based on that base period is 89,700 AFY.

1.6 Groundwater Model Predictive Scenarios

Two predictive scenarios were examined using the updated and recalibrated Basin Model to evaluate how groundwater levels and storage respond to varying groundwater pumping and recharge conditions. The variables included water demand and the amount of Nacimiento Water Project delivery. The model runs were simulated for a period of 29 years (water years 2012-2040) with a semiannual stress period. For the two scenarios, the hydrologic conditions (e.g., rainfall) that occurred during the hydrologic base period (the 29 years from October 1981 through September 2010) were simply repeated for 29 years into the future (i.e., 2012-2040). The hydrologic base period represents "wet", "dry" and "average" rainfall cycles which are characteristic of the Basin area.

Model Run 1, Baseline[6] with No Growth, was developed to determine the response of the Basin to continuation of 2011 Nacimiento Water Project delivery, 2011 water demands, and no growth projected 29 years into the future (2012-2040). Accordingly, actual 2011 Nacimiento deliveries were used as input for every year. For water demands, 2011 values were repeated every year for 29 years with no growth.

Model Run 2, Baseline with Growth, examined the response of the Basin to Nacimiento Water Project deliveries projected to occur after September 2011, projected water demands, and a growth rate of 1% per year projected 29 years into the future[7]. Accordingly, Model Run 2 used actual Nacimiento

6 The baseline is representative of Basin conditions in water year 2011.

7 The projected 1% growth does not take into account the urgency ordinance (No. 3246) on new or expanded development of groundwater supplies in the Paso Robles Basin area.

deliveries for 2012-13 and those forecast for 2014-2040. For agricultural water demand, the 2011 acreages for all non-vineyard crops (e.g., alfalfa, etc.) were kept steady into the future; this is reasonable given relatively flat historical trends. For vineyards in 2012, the actual 2012 vineyard acreages were applied directly. For future years, forecasts developed by the modeling subcommittee for vineyards to be planted by July 2013, 2014, and 2017 were combined with the 2012 vineyard coverage to develop complete vineyard coverages from 2013 through 2017. Thereafter, a 1% growth rate in vineyard acreage was assumed from 2018 to 2040, with the growth applied spatially over the 2017 vineyard coverage. A 1% annual increase was also applied to municipal, private domestic and small commercial pumping.

Modeling results for Model Runs 1 and 2 are described in this report in terms of average annual water budgets, groundwater basin storage by year, and changes in groundwater levels. As shown in Table ES-1 below, total outflow would exceed total inflow on average 5,592 AFY and 26,159 AFY under the No Growth and Growth scenarios, respectively.

Table ES-1. Summary of Average Annual Water Budgets for Model Run 1 (No Growth) and Model Run 2 (Growth)

Flux Terms		Unit	Model Run 1	Model Run 2
Inflow	Deep Percolation of Direct Precipitation and Return Flow from Applied Irrigation Water	AFY	22,311	24,916
	Deep Percolation of Streambed Seepage	AFY	27,938	27,537
	Subsurface Inflow	AFY	47,612	37,590
	Nacimiento Reservoir Water Project Supplies	AFY	139	5,451
	Deep Percolation of Discharged Treated Wastewater Effluent	AFY	6,789	7,909
	Deep Percolation of Urban Water and Sewer Pipe Leakage	AFY	398	464
	Average Annual Total Inflow	**AFY**	**105,187**	**103,867**
Outflow	Groundwater Pumping	AFY	95,749	110,742
	Evapotranspiration by Riparian Vegetation	AFY	3,453	3,453
	Groundwater Discharge to Rivers	AFY	10,133	11,937
	Subsurface Outflow	AFY	1,444	1,447
	Average Annual Total Outflow	**AFY**	**110,779**	**130,027**
Average Annual Change in Groundwater Storage (Total Inflow – Total Outflow)		AF	-5,592	-26,159
Cumulative Changes in Groundwater Storage Over the 29-Year Modeling Period		AF	-162,163	-758,621

Figure ES-7 shows that at the end of the model simulation in WY 2040, the cumulative change in groundwater storage would be a decline of 162,163 acre-ft for the no growth scenario and a decline of 606,102 acre-ft for the growth scenario.

Figure ES-7. Predicted Annual and Cumulative Change in Storage for Paso Robles Groundwater Basin Model Runs 1 and 2 (Water Years 2012-2040)

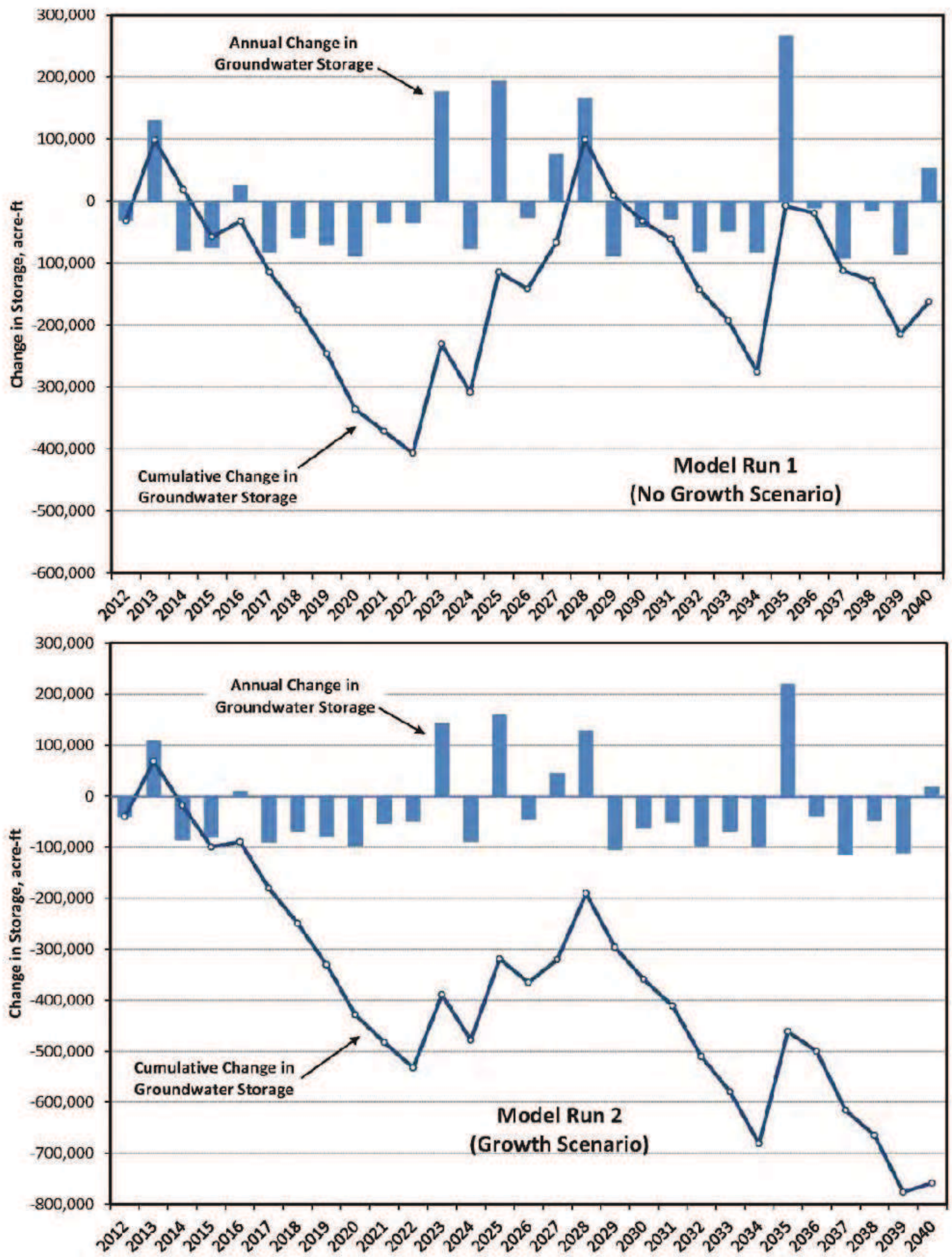
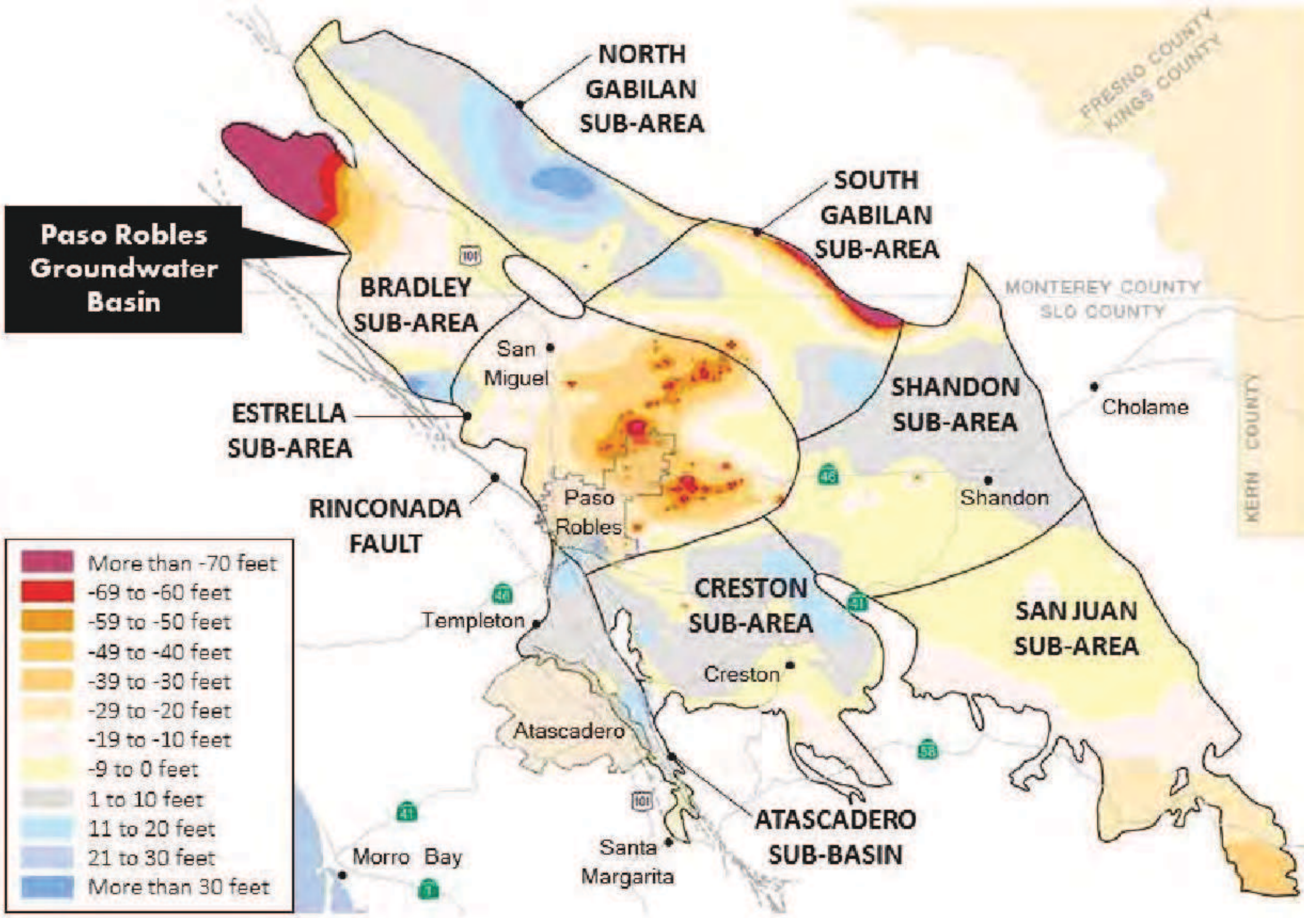


Figure ES-8 below shows that under the Model Run 1 (No Growth scenario) conditions, groundwater levels would decline more than 70 feet in the northern portion of the Bradley Sub-Area, along the eastern boundary of the South Gabilan Sub-Area, and within the central portion of the Estrella Sub-Area.

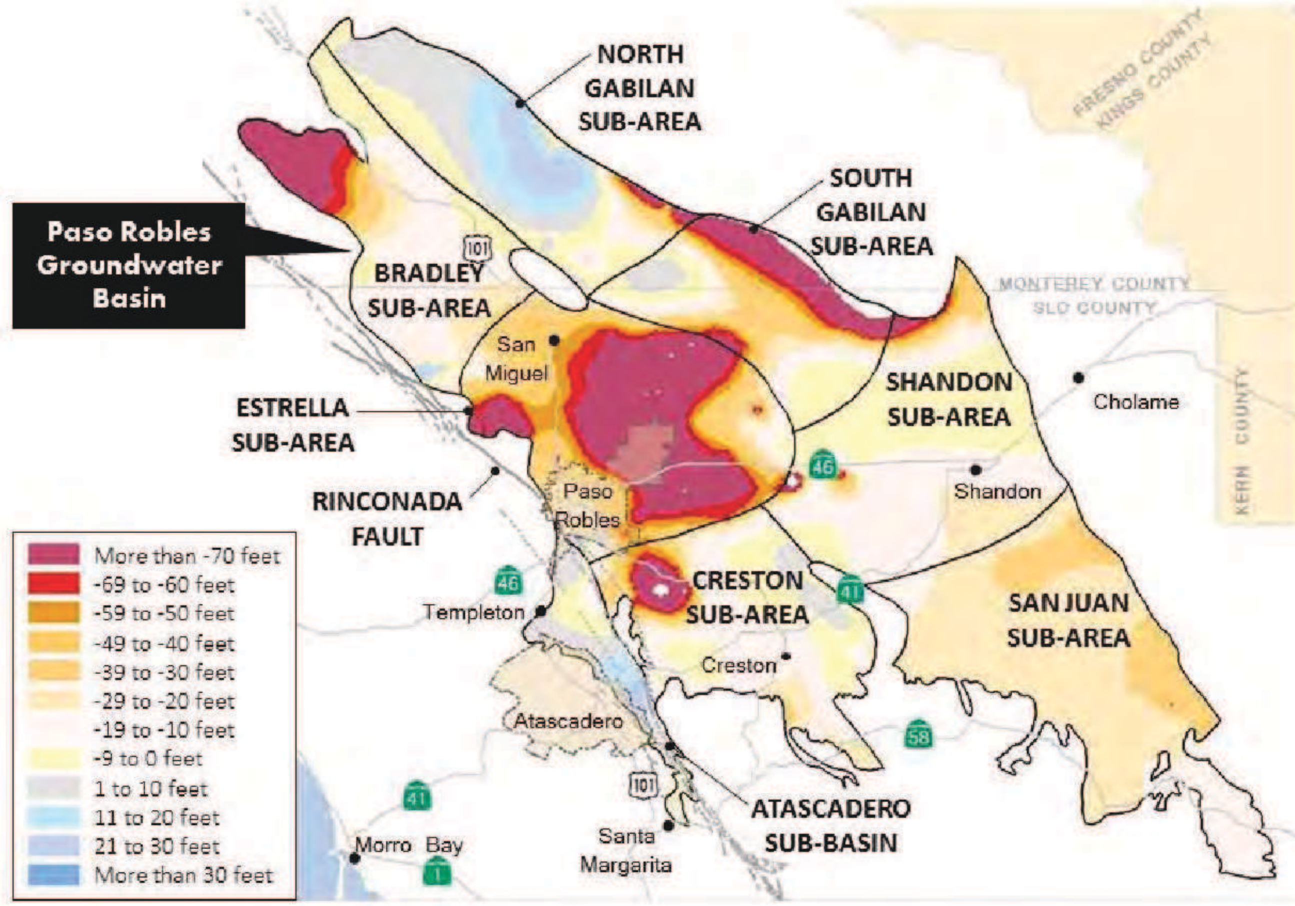
Figure ES-8. Change in Layer 4 Groundwater Elevations (2012-2040) – Model Run 1



Note: Change in groundwater elevations were also generated for model layers 1-3 for Model Run 1 and Model Run 2 conditions. Results provided in Figures ES-8 and ES-9 are for model layer 4, where changes in groundwater elevations are predicted to be highest under the no growth and growth scenarios.

Figure ES-9 below shows that under Model Run 2 (Growth scenario) conditions, the area of groundwater level declines in excess of 70 feet are more pronounced in the South Gabilan and Estrella Sub-Areas, and includes a significant area in the northwestern portion of the Creston Sub-Area.

Figure ES-9. Change in Layer 4 Groundwater Elevations (2012-2040) – Model Run 2



1.7 Model Limitations and Uncertainty

The Basin Model is a useful tool for evaluating the effects on Basin water levels due to changing hydrological and land use changes. Nonetheless, it is a simplified approximation of a complex hydrogeologic system and has been designed with built-in assumptions. To address such uncertainty, the Basin Model Update was evaluated independently through a peer review provided by Fugro Consultants. Discussion among GEOSCIENCE, Todd Groundwater and Fugro representatives focused on issues including certain aquifer properties, and the relative amounts and areal distribution of subsurface inflow, streambed percolation and rainfall recharge.

1.8 Recommendations

Based on the post-review discussion by GEOSCIENCE, Todd Groundwater and Fugro, specific tasks have been defined to reevaluate and further refine the Basin Model. These include the following:

- Reevaluate fate and recharge mechanisms of water from the watershed entering the groundwater basin;
- Replace the recharge/streamflow modeling package used to simulate streamflow and groundwater discharges to rivers with a streamflow routing package;
- Reevaluate deep percolation of direct precipitation and agricultural return flows in the groundwater basin; and
- Establish an acceptable range of hydraulic conductivity values for the groundwater basin.

In addition, the following scenarios have been identified for potential simulation with the refined Basin Model:

<u>Baseline</u>

- Updated Baseline with Growth Run

<u>Specific Action Analyses</u>

- Analysis 1 – Demand Reduction Scenario
- Analysis 2 – Salinas River Recharge
- Analysis 3 – Offset Basin Pumping with Recycled Water

<u>Basin Management Objectives Analyses</u>

- Analysis 4 – Offset Water Demand in Estrella Sub-Area
- Analysis 5 – Additional Releases to Huer Huero Creek
- Analysis 6 – Additional Releases to Estrella Creek
- Analysis 7 – Offset Pumping in Creston Sub-Area with Supplemental Water
- Analysis 8 – Offset Pumping in Shandon Sub-Area with Supplemental Water

Refinement of the Basin Model will provide improved understanding and simulation of the groundwater-surface water relationship and response to recharge and discharge components as they vary through time. Also, these proposed predictive analyses using the refined Basin Model will provide Basin managers and stakeholders the means to identify the actions which may be most effective at stabilizing groundwater levels on a sub-regional level.

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